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NOTES

ON

PLATE-LAYING, MAINTENANCE, CURVES, POINTS AND CROSSINGS

W. H. COLE

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SHORT NOTES

FOR

RAILWAY ENGINEERS & PLATE-LAYERS.

NOTES

ON

PLATE-LAYING, MAINTENANCE, CURVES,

AND

POINTS AND CROSSINGS.

(INTENDED CHIEFLY
FOR THE USE OF ENGINEERS AND PLATE-LAYERS
ON METRE-GAUGE RAILWAYS IN INDIA.)

BY

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"*Mente manuque.*"

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PREFACE.

THESE Notes were begun at the suggestion of one of my subordinates, and have already, in an unfinished state, been used by some of my brother engineers and plate-layers in India.

They contain all the information that will generally be required for ordinary work in plate-laying, maintenance, laying out curves, and putting in points and crossings, more especially on metre-gauge railways;—information which is only to be found scattered in various books of reference, or to be obtained by experience.

Although in the first place intended for engineers and plate-layers on Indian metre-gauge railways, these Notes may be, I think, of interest and of use to others also.

The permanent-way inspector of to-day—so far as my knowledge of him in India goes—is not merely that vague product, a "practical man." He does not necessarily prefer guess-work to certainty. He has not a serene confidence in that fallacious method of the old plate-layers called "putting it in by the eye." He has not a supreme contempt for a simple and intelligible trigonometrical method; and I have usually found that he has Donaldson's books on Points and Crossings, which shows that he wants to understand exactly what he is about.

The nomenclature in Donaldson's books is, however, necessarily complicated, and the simpler treatment adopted in these Notes will, it is hoped, meet all ordinary cases.

The general case of Points and Crossings may be treated in two ways.

By one method, the radius of the curve which lies on the gauge-line and the crossing is first determined. The lead is then calculated with reference to the portion of this curve intercepted between the crossing and the heel of the switch.

By the other method, the length and divergence of the switch being given, the lead is calculated with reference to the curve which would touch the direction of the crossing at the nose, and that of the switch at the heel.

I have already mentioned that I began this little work at the suggestion of one of my inspectors. I would now add that to several, and especially to Messrs. Beaty, Arnott, and Le Feuvre, am I indebted for advice and help.

Finally, my thanks are due to my friend, Mr. J. T. Dewar, C.E., who not only revised these Notes, but offered many suggestions which I have gladly adopted.

W. H. C.

August, 1885.

CONTENTS.

PLATE-LAYING 1

MAINTENANCE 4

CURVES :—

I. Laying out Curves 8

II. Serpentine Curves... 10

III. Diversions 11

IV. Cant and Gauge on Curves 12

POINTS AND CROSSINGS :—

I. General Case—Two Methods 13

II. Metre-Gauge Crossings on Indian State Railways ... 19

III. What Crossing to use 22

IV. Crossovers 24

V. A Diagonal or Pick-up Line—Limiting Angle ... 25

VI. Metre Gauge crossing Broad Gauge 27

VII. Triangles 28

VIII. General Remarks 29

RECAPITULATION OF USEFUL FORMULÆ :—

I. Laying out Curves 30

II. Serpentine Curves ... ... *ib.*

III. Diversions 31

IV. Cant on Curves ... ... *ib.*

V. Points and Crossings ... ... *ib.*

VI. Crossovers 32

VII. Diagonals or Pick-up Lines ... ... *ib.*

PLAIN RULES FOR BEGINNERS 33

PLATE-LAYING.

THE road having been properly dressed off at formation level, ballast is spread, and sufficient material for beginning the plate-laying collected at the starting-point.

It is easier to lift than to lower a road, and less ballast, therefore, should be laid than will ultimately be required under the sleepers.

To do the work quickly, a large number of men will be necessary; but they must be arranged according to the details of the work which they have to do. Confusion and overcrowding must be avoided, and every man must be usefully employed.

Assuming that we are laying a Metre-gauge Line, the following labour would probably be required on the first day:—

Description.	*No.*	*Rate.*			*Amount.*			*Remarks.*
		Rs.	as.	p.	Rs.	as.	p.	
Beldars	4	0	2	6	0	10	0	Oiling fish-bolts.
Coolies	20	0	2	0	2	8	0	Carrying and placing sleepers.
Beldars	8	0	4	0	2	0	0	Carrying and laying rails on sleepers.
Beldars	2	0	2	6	0	5	0	Carrying fish-plates and bolts, and assisting wrenchmen to fish the joints.
Wrenchmen	2	0	3	0	0	6	0	Fishing the rails together.
Carpenters	3	0	6	0	1	2	0	Countersinking bearing-plates. Making tool-handles, and distance-wedges for wrenchmen. Nicking the sleepers if necessary.
Boys	2	0	2	0	0	4	0	Carrying bolts and plates for wrenchmen.

In fishing the rails together the wrenchmen place ¼-inch distance-wedges between the ends of the rails, to allow for expansion.

On the second and succeeding days the following labour might be employed:—

Description.	*No.*	*Rate.*			*Amount.*			*Remarks.*
		Rs.	as.	p.	Rs.	as.	p.	
Trollymen	24	0	4	0	6	0	0	With material trollies.
Mate	1	0	5	0	0	5	0	In charge of trollies.
Beldars	16	0	4	0	4	0	0	Carrying rails.
Coolies	40	0	2	0	5	0	0	Carrying sleepers.
Mate	1	0	5	0	0	5	0	In charge of carriers.
Beldars	4	0	2	6	0	10	0	Oiling bolts.
Boys	4	0	2	0	0	8	0	Carrying and placing spikes on sleepers, &c.
Augermen	8	0	4	0	2	0	0	Boring sleepers and spiking.
Levermen	8	0	2	6	1	4	0	Assisting augermen by holding up the sleepers to the rail with pinch-bars.
Wrenchmen	2	0	3	0	0	6	0	Fishing the rails together.
Beldars	4	0	2	6	0	10	0	Assisting wrenchmen.
Carpenters	3	0	6	0	1	2	0	Countersinking bearing-plates. Making tool-handles, and distance-wedges for wrenchmen. Nicking the sleepers if necessary.
Blacksmith	1	0	6	0	0	6	0	
Hammerman	1	0	3	0	0	3	0	Assisting blacksmith.
Mate	1	0	6	0	0	6	0	In charge of linking.
Bhistis	2	0	3	0	0	6	0	Giving water.

Three material-trollies will be enough if the lead does not exceed half a mile. For the first trolly, loaded with sleepers, eight trollymen will be required; for the second, loaded with rails, ten; and for the third, loaded with fastenings, six.

The mate in charge of the linking will see that the gauge is properly used by the augermen, and that the correct spacing of the sleepers is chalked on the rails, the chalk-marks being made first on one rail by measurement, and then by a square transferred to the opposite rail.

The augermen will space the sleepers according to the marks chalked on the rails, and while driving the spikes fix the rails at the proper gauge. A hole is first drilled with an auger, the size of which is somewhat less than the section of the spike; and care must be taken to drive the spike vertically, and to keep the sleeper square to the rail. Two augermen will gauge and spike each pair of rails, assisted by the levermen. Thus the eight augermen will be spiking four rail-lengths at the same time. A "rail-lifter" is a machine which has on many railways superseded the lever.

The linking gang will be followed by a packing gang, consisting of a mate, his assistant, and sixteen men.

Description.	*No.*	*Rate.*			*Amount.*			*Remarks.*
		Rs.	as.	p.	Rs.	as.	p.	
Mate	1	0	8	0	0	8	0	In charge.
Assistant do.	1	0	6	0	0	6	0	
Beldars	16	0	2	6	2	8	0	Packing, &c.

The duty of the mate is to straighten the road, and to lift the joint-sleepers with level-board, spirit-level, and height-board; or a plumb-level may be used.

The assistant mate will level the intermediate sleepers, and see that the road is properly packed.

The number and distribution of the men employed will of course vary with lines of a different gauge and type, and in all cases the inspector will exercise his discretion.

On bridges the distance between girder and rail is carefully measured from point to point. The sleepers are then cut on the lower side accordingly, and marked for their places, so that differences due to camber of girder, rivet-heads, and cover-plates may be allowed for.

MAINTENANCE.

For a length of three miles on a metre-gauge line a gang consisting of a mate, a wrenchman, and six beldars (two to the mile) will generally be sufficient for maintenance after the road has been in use for a year or two.

The ballast should be packed tightly under the sleeper where it carries the rail, and loosely under the middle, or the sleeper may snap.

The use of fang-bolts has been given up, but they would probably have been efficient if care had been taken to put them in perpendicularly to the slope of the foot of the rail instead of vertically. Nothing, however, can be better than the bearing-plate and spikes, the fastening which has superseded fang-bolts for joint-sleepers on Indian State Railways.

The renewals of fish-bolts will be greatly lessened if they are occasionally oiled.

It is advisable to lubricate the spike with soap before driving it into a sleeper of very hard wood which is likely to split.

When a sleeper is loose, the rail (if of wrought iron) yields at that place, and is flattened out. Every succeeding train drops heavily on the spot, and aggravates the mischief. In a few days a rail is thus rendered useless which might have lasted for years.

While working regularly over a length, therefore, from day to day, a careful mate will not neglect cases of isolated loose sleepers. Wherever a rail is beginning to bulge, it will be found that the sleeper below is not properly packed, and the cause of the mischief must be dealt with at once.

If a beldar were sent along with the wrenchman to pack such loose sleepers and so save the rails from rapid destruction, his separation from the gang might offer facilities for shirking work. In two days, however, the mate and gang can pack about one-fifth of a mile. On the third day let the mate go carefully over his length with one or two beldars to pack loose sleepers as they occur. The rest of the gang, being left to dress the ballast of the road which has been packed during the previous two days, have their appointed task, which they cannot shirk without detection. In this way the whole length can be regularly worked through without the neglect of any portion.

The above remarks apply more particularly to wrought-iron rails, a large proportion of which will remain in the road for some years, although they are gradually being replaced by steel.*

---

* Steel, as a permanent-way material, has within a few years so completely superseded wrought iron that a short account of its manufacture into rails is here given.

The water, sulphur, and arsenic are first expelled from the hæmatite ore by roasting in a kiln.

The ore, thus rendered porous, is then reduced in blast furnaces. These are charged from time to time at the top with ore, coke, and limestone, and the blast is supplied through tuyères near the bottom. The slag flows off at a higher level than the heavier metal, which is either run into pigs and called "pig iron," or carried at once in a molten state to the Bessemer converters in travelling ladles.

The Bessemer converters are huge iron retorts, swung on trun-

The 41¼lb. rails in use on Indian metre-gauge railways were not designed to bear engines of the weight and speed now required, and it is intended to relay certain portions of the Raj^{a}-Malwa Railway with a rail of 50lb. section. The heavy goods trains, driven often at a very high rate of

---

nions, and having a capacity, perhaps, of 12 tons, in which, by driving a powerful blast through the molten mass for twenty or twenty-five minutes, it is reduced to a state of pure iron.

The converter is then swung down to receive the molten *spiegeleisen*, or ferro-manganese, flowing from a cupola close by. This admixture gives the required proportions of carbon and manganese.

The slag having been run off, the molten steel is poured into a ladle, and thence into the moulds. The ladle being tapped at the bottom by raising a plug, the slag and other floating impurities are nearly all left behind.

When the steel has solidified, the moulds are lifted off, and the ingots re-heated in a furnace. After passing the ingot through the "cogging" or "blooming" rolls, the rough ends are sheared off, and it is divided if necessary into "blooms," either by shearing or under the hammer.

The blooms are then passed through the "roughing" rolls, and lastly through the "finishing" rolls.

The long piece of rail, while still hot, is sawn into lengths.

When cool, the rails are straightened, the lengths checked and corrected if necessary, the ends dressed, the holes drilled; and the rails are then stacked in tiers for inspection.

The composition of the steel depends upon the qualities required. Thus for rails and ship-plates the proportions may be compared :—

	Rails.	*Ship-plates.*
Iron ...	98·47	99·27
Carbon ...	0·35	0·14
Manganese	1·01	0·47
Silicon ...	0·05	0·02
Sulphur	0·06	0·04
Phosphorus	0·06	0·06
	100·00	100·00

speed on falling gradients, try the present light-section rail most severely.

The amount of renewals annually required will probably vary in the following way. During the first few years the renewals will diminish annually as the defective material is gradually weeded out. During a second period the renewals will be comparatively light for several years. Then, as the life of the rails, &c. is reached, very heavy extraordinary renewals will suddenly become necessary. Probably not for many years will the annual renewals conform to a general average.

It is obvious, therefore, that while locomotive and traffic expenses need only vary year by year with the expansion or contraction of traffic, the expenses of maintaining the permanent-way must frequently appear to be irregular and excessive. This should not necessarily be regarded as a sign of imperfect maintenance. On Guaranteed Indian railways this fluctuation is, I believe, arranged for by a "Renewal Fund." Where no renewals have been made during the year an allowance for wear and tear is debited. This system might with advantage be adopted on State railways also.

CURVES.

I.—LAYING OUT CURVES.

(1.) *By Chain and Offsets :—*

To lay out the curve in equal chords, C, produce the tangent from the first point on the curve to a distance = C. Set off the offset $\frac{O}{2} = \frac{C^2}{2R}$. This will fix a second point on the curve. Produce the line joining the first and second points on the curve to a distance = C. Set off the offset $O = \frac{C^2}{R}$. This will fix a third point on the curve. A fourth point may be found in the same way as the third, and so on; the last offset, however, being $\frac{O}{2}$ as at first (see fig. 1).

(2.) *By Chain and Theodolite :—*

The tangential angle θ is first calculated for the given chord C and radius R (the chord being commonly 100 feet). The theodolite having been put up at the first point, the vernier reading zero and the axis of the telescope being in the direction of the tangent, the tangential angle is set off, and the chord C is measured along this direction, by which a second point on the curve is fixed. The theodolite is then directed so as to make an angle $2\,\theta$ with the tangent. From the second point a chord, C, is measured intersecting this direction, and a third point on the curve is thus fixed.

This process is continued to the end of the curve. If a distance less than C finally remains to complete the curve, the additional angle will be proportional to this distance.

If it be impossible to see the whole length of the curve from the first point, the instrument can be transferred to the last point set out. The vernier now reading $n\theta$, the telescope is directed on the first point, and then moved round until the vernier reads $2n\theta$. Reversing the telescope, its axis now coincides with the direction of the tangent at the point, and the process can be continued as at first.

In fig. 2 let—

R = radius of curve;
C = length of chord;
O = offset from chord produced to a distance C;
T = length of tangent;
ϕ = half the angle formed by the intersection of the tangents;
θ = tangential angle of chord C;
X = length of curve;
Y = distance from point of intersection of tangents to middle of curve;
v = versed sine of the chord C;
V = versed sine of the chord on the whole curve:

Then we have—

$$\left.\begin{aligned} O &= \frac{C^2}{R} \\ &= 8v \text{ (approximately)} \end{aligned}\right\} \quad \ldots\ldots\ldots(1)$$

$$\underset{\text{(in minutes)}}{\theta} = \frac{1719\,C}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$T = R \cot \phi \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$\left.\begin{aligned} C &= 2\sqrt{(2R-v)\,v} \\ &= \sqrt{8Rv} \text{ approximately} \end{aligned}\right\} \quad\ldots\ldots(4)$$

$$\left.\begin{aligned} v &= R-\sqrt{R^2-\left(\frac{C}{2}\right)^2} \\ &= \frac{C^2}{8R} \text{ approximately} \end{aligned}\right\} \quad\ldots\ldots(5)$$

$$X = 0{\cdot}000582\,R\,(5400-\phi) \quad\ldots\ldots\ldots\ldots\ldots(6)$$

(where ϕ is expressed in minutes)

$$Y = R(\operatorname{cosec}\phi-1) \quad\ldots\ldots\ldots\ldots\ldots(7)$$

$$V = R(\text{coversine } \phi) \quad\ldots\ldots\ldots\ldots\ldots(8)$$

As it is convenient when possible to choose curves whose tangential angles for chords of 100 feet are ½°, 1°, 1½°, 2°, and so on, it should be remembered that for a curve whose radius is 2864·8 feet the tangential angle is 1°; and, generally, if n = number of degrees of tangential angle:

$$R = \frac{2864{\cdot}8}{n} \quad\ldots\ldots\ldots\ldots\ldots(9)$$

II.—SERPENTINE CURVES.

In figure 3, let the inclination δ of AH to GB be given; the radii R r; and either the point A, and the distance D_1 between the lines measured perpendicularly from A; or the point B, and the distance D_2 between the lines measured perpendicularly from B.

Then,

$$\begin{aligned} \cos\beta &= \frac{FK}{EF} \\ &= \frac{FB+BK}{EC+CF} \\ &= \frac{FB+AM-AL}{EC+CF} \\ &= \frac{FB+(AE-AG)\cos\delta}{EC+CF} \end{aligned}$$

Hence,
$$\cos\beta = \frac{r+(R-D_1)\cos\delta}{R+r} \quad \ldots\ldots\ldots\ldots(10)$$

$$\cos\alpha = \frac{R+(r-D_2)\cos\delta}{R+r} \quad \ldots\ldots\ldots\ldots(11)$$

$$\beta - \alpha = \delta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

The length of the tangents T_1 T_2 can now be calculated, the lines A N C P B traced out on the ground, and the curves set off.

If the lines are parallel, and $R=r$:

$$\cos\beta = \frac{2R-D}{2R} = \cos\alpha \ldots\ldots\ldots\ldots(13)$$

III.—DIVERSIONS.

In figure 4, let O be the maximum offset required. Then $O=2v$.

Let $4c=2C=$length of line to be diverted. Then—

$$C = 2\sqrt{(2R-v)v}$$

$$\therefore\ c = \sqrt{\left(2R-\frac{O}{2}\right)\frac{O}{2}}$$

$$\left.\begin{aligned} \therefore\ c &= \sqrt{\left(R-\frac{O}{4}\right)O} \\ &= \sqrt{OR} \text{ approximately} \end{aligned}\right\}\ (14)$$

The approximate formula can be easily remembered and applied.

The offsets at the quarter, half, and three-quarters distances—c, $2c$, $3c$—will be $\frac{O}{2}$, O, and $\frac{O}{2}$ respectively.

The points of inflexion will be at the quarter and three-quarters distances.

The evenness of the curves may be tested by seeing if the versed sine upon a chord of any convenient length is the same throughout.

IV.—CANT AND GAUGE ON CURVES.

(1.) On metre-gauge railways the gauge on curves should be $3'\ 3''\frac{7}{8}$, except in the case of very flat curves.

(2.) The cant is obtained partly by the depression of the inner rail, and partly by the elevation of the outer rail.

The rise should begin some little distance back on the straight, increasing gradually until the full cant or superelevation of the outer rail is obtained at the beginning of the curve. If this be not done, the curve is liable to be pushed out at its commencement—a not uncommon fault.

Let E = superelevation of outer rail;
G = gauge;
V = maximum velocity of trains;
R = radius of curve:

Then,
$$E = G\frac{V^2}{1{\cdot}25R} \quad \text{.............................}(15)$$

(E being in inches, V in miles per hour,
G and R in feet)

The following formula, in which E, G, V are all to be expressed in the same unit of length, the time-unit being one second, may be useful:—

$$E = G\frac{V^2}{32R} \quad \text{.................................}(16)$$

Practically for the metre gauge the versed sine of a chord in feet equal to the velocity in miles per hour = E. This easy rule was given, I believe, by Mr. B. W. Blood, M.I.C.E.

POINTS AND CROSSINGS.

I.—*GENERAL CASE—TWO METHODS.*

Let G = gauge, measured from inside of rail to inside of rail;

α = angle of crossing;

R, r = radii of curves;

d = clearance at heel of switch;

δ = angle of divergence of switch;

l = length of switch;

L' = distance from nose of crossing to springing of curve, *i.e.* to the point where the curve of branch rail would touch gauge-line of straight main rail;

l' = distance from heel of switch to springing of curve;

L = lead, or distance from nose of crossing to heel of switch;

I = distance from nose of crossing to the point at which the divergence is unity. I may be called the number of the crossing when expressed by the nearest integer. Thus, if the inclination is 1 in 7·35, the crossing may be conveniently called a 1 in 7 crossing.

The general case may be treated in two different ways. For simplicity, the main line will be assumed to be straight, but it will be seen afterwards that the application to cases where the lines are curved is very easy.

(1.) The first and usual method of calculating the lead is as follows:—

For a given gauge and crossing a certain curve can be found which would rest tangentially on the gauge-line and the crossing. This curve, however, would only be continued for a certain distance from the nose of the crossing, viz. to the point at which its offset from the gauge-line would be the same as the clearance of the switch. This distance is called the Lead. From that point the line is continued by the switch, the toe of which touches the gauge-line of the main rail.

Referring to figure 5, we have—

$$I = \cot \alpha \quad \text{(17)}$$

$$R = \frac{G}{\operatorname{versin} \alpha} \quad \text{(18)}$$

$$L' = R \sin \alpha \quad \text{(19)}$$

$$\left.\begin{aligned} L' &= G \cot \frac{\alpha}{2} \\ &= 2GI \text{ (approximately)} \end{aligned}\right\} \quad \text{(20)}$$

The latter approximate formula is the well-known Platelayer's Rule for the Lead—viz.: Multiply twice the gauge by the number of the crossing. This, however, it must be carefully observed, does not really give the lead. Like the two preceding formulæ, it merely gives the distance from nose of crossing to springing of curve, supposing that the curve were continued until it touched the gauge-line, instead of being intercepted by the switch. From that distance a deduction will have to be made to obtain the lead.

Continuing the formulæ:

$$\left.\begin{aligned} L' &= \sqrt{(2R-G)G} \\ &= \sqrt{2RG} \text{ approximately} \end{aligned}\right\} \text{......(21)}$$

In the same way, when we have curve leaving curve, instead of curve leaving straight, the formulæ—

$$L' = \sqrt{\frac{2RrG}{R+r}} \quad \text{........................(22)}$$

for curves diverging, and

$$L' = \sqrt{\frac{2RrG}{R-r}} \quad \text{........................(23)}$$

for curves converging, may be used. These are easily obtained.

Thus, if s and $G \pm s$ be the distances from the nose of the crossing to the tangential gauge-lines at springing produced, as in fig. 6—

$$\left.\begin{aligned} L' &= \sqrt{2Rs} \\ L' &= \sqrt{2r(G \pm s)} \end{aligned}\right\}$$

and eliminating s,

$$L' = \sqrt{\frac{2RrG}{R \pm r}}$$

Once having found the crossing, however, which will suit curve leaving straight or curve leaving curve, the lead will be the same for that crossing in any case.

Thus, whether on the metre gauge a 1 in 6¾ crossing be put in for a 300-ft. curve leaving straight, or for two 600-ft. curves, the lead will be 31 ft.

Continuing the formulæ:

$$l' = \sqrt{2Rd} \quad \text{........................(24)}$$

and finally,

$$L = L' - l' \quad \dots\dots\dots\dots\dots\dots\dots\dots (25)$$

$$\left.\begin{aligned} &= R \sin a \\ &= G \cot \frac{a}{2} \\ &= 2GI \\ &= \sqrt{(2R-G)G} \\ &= \sqrt{2RG} \end{aligned}\right\} - \sqrt{2Rd}$$

$$\text{or } L = \sqrt{\frac{2RrG}{R \pm r}} - \sqrt{\frac{2Rrd}{R \pm r}}$$

By the first method, then, the lead is calculated without reference to the length of the switch. It is assumed that a switch of suitable length will be used having the given clearance *d*.

EXAMPLE 1.—Let $G = 1$ metre;
$a = 7^\circ\ 45'$;
$d = 0{\cdot}09$ metre:

Then,

$$\begin{array}{lcccl} & & & & \text{Metres.} \\ R & = & \dfrac{1}{\text{versine } 7^\circ\ 45'} & = & 109{\cdot}48 \\ L' & = & R \sin 7^\circ\ 35' & = & 14{\cdot}76 \\ l' & = & \sqrt{2R \times 0{\cdot}09} & = & 4{\cdot}44 \\ L & = & L' - l' & = & 10{\cdot}32, \text{ or } 33{\cdot}85 \text{ ft.} \end{array}$$

(**2.**) It generally happens that a certain crossing and switch are given to be used together, and in the second method of calculation the length and divergence of the switch are taken into account, the directions of the switch and crossing being assumed to be tangential to the curve where it meets the heel of the switch and the nose of the crossing.

Referring to figure 7, we have—

$$\sin \delta = \frac{d}{l} \quad \text{.....................(26)}$$

Again,

$$\begin{aligned} \angle \text{CED} &= \angle \text{KCE} \\ &= \angle \text{KCF} + \angle \text{FCE} \\ &= \angle \text{KCF} + \angle \text{FEC} \\ &= \delta + \alpha - \angle \text{CED} \end{aligned}$$

But

$$\therefore \angle \text{CED} = \frac{\alpha + \delta}{2}$$

Again,

$$\begin{aligned} \text{L} &= \text{DE} \\ &= \text{CD} \cot \text{CED} \end{aligned}$$

$$\therefore \text{L} = (\text{G} - d) \cot \frac{\alpha + \delta}{2} \quad \text{..................(27)}$$

EXAMPLE 2.—Let

$$\begin{aligned} \text{G} &= 1 \text{ metre} \\ l &= 3{\cdot}63 \text{ metres} \\ d &= 0{\cdot}09 \text{ metre} \\ \alpha &= 7^\circ\, 45' \end{aligned}$$

these dimensions being taken from the Type Drawings for Indian State Railways.

Then,

$$\sin \delta = \frac{0{\cdot}09}{3{\cdot}63}$$

$$\therefore \delta = 1^\circ\, 25'$$

$$\begin{aligned} \text{L} &= (\text{G} - d) \cot \frac{\alpha + \delta}{2} \\ &= 0{\cdot}91 \cot 4^\circ\, 35' \\ &= 11{\cdot}35 \text{ metres, or } 37{\cdot}23 \text{ feet.} \end{aligned}$$

In the Type Drawings, however, the radius of the curve is given as 100 metres, and the lead as 44·2 feet; and these dimensions are near enough for all practical purposes, although, as we have seen, they differ a good deal from the results obtained in EXAMPLES 1 and 2.

The lead given in the Type Drawings is apparently calculated from the formula $L' = R \sin a$ (R being taken as 100 metres); and the deduction of l', which is required to obtain L, the correct lead, is not made.

Thus, referring to figure 8,

$$\begin{aligned} R \sin a &= 100 \sin 7^{\circ}\ 45' \\ &= 13{\cdot}48 \text{ metres, or } 44'\ 3'' \end{aligned}$$

This is treating the case as if the curve, instead of running into the heel of the switch, met the gauge-line of the main rail tangentially at the point.

When the accurate lead is put in, we have one even curve having the longest radius possible with the given switch and crossing.

When we put in a longer lead, we have a compound curve, flatter near the switch, and sharper at the crossing, than the proper curve. Looking at a 1 in 7 crossing laid with a 44 ft. or 45 ft. lead, the flatness of the curve towards the heel of the switch and its sharpness towards the nose of the crossing are at once noticed.

It is obvious, therefore, that no advantage is gained, and the radius of the curve is not improved by putting in a longer lead than the correct one. Practically, however, the angle of a crossing is defined by such short lines that small differences in the length of the lead may be allowed. For instance, in practice it is not convenient to cut rails if the lead can be nearly obtained without doing so.

II.—METRE-GAUGE CROSSINGS ON INDIAN STATE RAILWAYS.

The crossings at present in use are known as the 1 in 7, the 1 in 10, and the 1 in 5.

(1.) *The* 1 *in* 7 *Crossing:—*

The angle of a 1 in 7 crossing is 7° 45′, which gives an inclination of 1 in 7·35.

The radius of the curve is given as 100 metres, or 328 ft. in the Type Drawings.

The lead, or distance from nose of crossing to heel of switch, is given as 13·49 metres, or 44′ 3″.

To set off the direction of a 1 in 7 crossing by measurement.—The perpendicular offset at a distance of 100 feet from the nose of the crossing is 13′ 7″5/16. Thus:

$$\begin{aligned} O &= 100 \tan 7^\circ 45', \text{ or } \frac{100}{I}\left(i.e. \frac{100}{7{\cdot}35}\right) \\ &= 13{\cdot}61 \text{ feet.} \end{aligned}$$

This rule will enable the plate-layer to produce the direction accurately to any distance across a yard without having to use a theodolite.

To test a 100 metre curve.—The versine on a chord of 50 feet is 11½ inches. Thus:

$$\begin{aligned} v &= \frac{C^2}{8R} \text{ approximately (formula 5)} \\ &= \frac{2500}{2624} = 0{\cdot}95 \text{ feet} = 11\tfrac{1}{2} \text{ inches} \end{aligned}$$

(2.) *The* 1 *in* 10 *Crossing:—*

The angle of a 1 in 10 crossing is 5° 30′, which gives an inclination of 1 in 10·43.

The radius of the curve is given as 200 metres, or 656 ft.

The lead is given as 19·20 metres, or 63′ 0″. Thus:

$$\begin{aligned} L' &= R \sin a \\ &= 200 \sin 5^\circ 30' \\ &= 19{\cdot}2 \text{ metres} \end{aligned}$$

To set off the direction of a 1 in 10 crossing by measurement.—The perpendicular offset at a distance of 100 feet is 9′ 7″½.

To test a 200 metre curve.—The versine on a chord of 50 feet is 5¾ inches.

(3.) *The* 1 *in* 5 *Crossing:—*

The angle of a 1 in 5 crossing is 11° 0′, wihich gives an inclination of 1 in 5·24.

The radius of each of the diverging curves is given as 100 metres, or 328 feet.

The lead is given as 9·54 metres, or 31′ 3″. Referring to figure 9, this is apparently obtained as follows, the deduction necessary to determine the correct lead not being made:—

$$\begin{aligned} R \sin \frac{a}{2} &= 100 \sin 5^\circ 30' \\ &= 9{\cdot}58 \text{ metres, or } 31' \; 33'' \end{aligned}$$

To set off the directions.—Each makes with the bisecting line an angle of 5° 30′, the perpendicular offset of which at a distance of 100 feet is 9′ 7″½.

To test the 100 metre curves.—As before, the versine on a chord of 50 feet is 11½ inches.

With Circular No. 4 of 1882 were issued diagrams of Standard Crossings, which have not yet been brought into use. The leads given in these diagrams are as nearly accurate as can be desired in any case.

The crossings are the 1 in 6¾, the 1 in 9½, and the 1 in 12. The following cases may be noted:—

a.—Main line straight; Radius of branch 300 feet; Crossing 1 in 6¾; Angle 8° 30′; Lead 31 feet. This may be easily obtained:

$$\begin{aligned} \mathrm{L} &= \mathrm{L}' - l' = \mathrm{R} \sin \alpha - \sqrt{2\mathrm{R}d} \\ &= 300 \sin 8^\circ\, 30' - \sqrt{600\left(\tfrac{3\frac{5}{8}}{12}\right)} \\ &= 44 - 13 \\ &= 31 \text{ feet} \end{aligned}$$

b.—Curves diverging; Radius of each 600 feet; Crossing 1 in 6¾; Angle 8° 30′; Lead 31 feet.

c.—Main line straight; Radius of branch 600 feet; Crossing 1 in 9½; Angle 6° 0′; Lead 44 feet.

d.—Main line straight; Radius of branch 950 feet; Crossing 1 in 12; Angle 4° 45′; Lead 55 feet.

e.—Curves diverging; Radius of each 1200 feet; Crossing 1 in 9½; Angle 6° 0′; Lead 44 feet.

Of these arrangements, *a* is only to be used for temporary sidings to which engines are not admitted; *b* and *c* are to be used for ordinary work in stations. *d* and *e* for junctions and similar positions where an easy curve is of more importance than economy of space.

The clearance at heel of switch in these diagrams is 3⅝ inches or 0·30208 feet.

On Indian State Railways the gauge is measured from inside to inside of rail; and the apex of the crossing, being formed by the intersection of the lines of the inside edges of the rails, is an imaginary point a little *in front of* the blunt nose of the crossing.

In Donaldson's books the gauge is measured from centre to centre of rail; and the apex of the crossing, being determined by the intersection of the centre lines of the rails, is an imaginary point a little *behind* the blunt nose of the crossing.

In both cases it is to those imaginary points that all calculations and measurements refer.

If reference is made to Donaldson's "Tables for Platelayers," it must be to Table V. for the metre gauge. It is nominally for 3′ 6″ gauge; but, bearing in mind that this is measured from centre to centre of rail, it is clear that the following measurements quoted from that table very nearly apply:—

CROSSING 1 IN	LEAD.	CROSSING 1 IN	LEAD.
5	26	7½	39
5½	28	8	42
6	31	9	47
6½	34	10	52
7	36	11	57

As regards other portions of the Table, it must be remembered that the clearance at heel of switch, the least admissible radius, the intervals between the roads, and other data on which the calculation of the measurements depends are different from those adopted on Indian State Railways.

III.—WHAT CROSSINGS TO USE.

(1.) *Curve branching from Straight:—*

$$I = \frac{1}{\sin \alpha} \text{ approximately}$$

$$= \frac{R}{L'}$$

$$= \frac{R}{\sqrt{(2RG)}}$$

$$\therefore \quad I = \sqrt{\frac{R}{2G}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (28)$$

Example 3.— Let R = 100 metres
G = 1 metre

Then, $I = \sqrt{\frac{100}{2 \times 1}} = \sqrt{50} = 7$ nearly

Hence in this case a 1 in 7 crossing would be suitable.

(2.) *Two Converging Curves:—*

In a similar way the formula—

$$I = \sqrt{\frac{Rr}{2(R-r)G}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (29)$$

may be obtained.

Example 4.—Let R = 600 metres
r = 150 metres
G = 1 metre

Then, $I = \sqrt{\frac{600 \times 150}{2(600-150) \times 1}}$
$= \sqrt{100}$
$= 10$

(3.) *Two Diverging Curves:—*

$$I = \sqrt{\frac{Rr}{2(R+r)G}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (30)$$

From the above formulæ the following common cases may be easily deduced for metre gauge:—

a.—Main line straight; Radius of branch 200 metres; Crossing 1 in 10.

b.—Main line straight; Radius of branch 100 metres; Crossing 1 in 7.

c.—Curves diverging; Radius of each 100 metres; Crossing 1 in 5.

d.—Curves diverging; Radius of each 200 metres; Crossing 1 in 7.

e.—Curves converging; Radii 200 and 100 metres; Crossing 1 in 10.

f.—Three Throws; Branch Roads (fig. 10*a*) diverging; Radius of each 100 metres; Crossings—A 1 in 5, B_1 and B_2 1 in 7.

g.—Three Throws; Branch Roads diverging; Radius of each 200 metres; Crossings—A 1 in 7, B_1 and B_2 1 in 10.

h.—Three Throws; Branch Roads (fig. 10*b*) converging; Radii 200 and 100 metres respectively; Crossings—A 1 in 7, B_1 and B_2 1 in 10.

IV.—CROSSOVERS.

In figure 11, let D = distance from centre to centre of tracks, and S = distance from nose to nose of crossings measured along the line.

$$S = (D - 2G) \cot \alpha \quad \ldots\ldots\ldots\ldots (31)$$

The following examples for metre gauge may be verified. Most of the tracks on Indian State Railways have so far been laid 12 feet apart, but the rule now is to lay the roads 13 feet and 15 feet apart in different cases:—

$D = 12$; $\alpha = 7^\circ\ 45'$ (1 in 7); $S = 39{\cdot}98$ ft.

$D = 13$; $\alpha = 7^\circ\ 45'$ (1 in 7); $S = 47{\cdot}33$ ft.

$D = 15$; $\alpha = 7^\circ\ 45'$ (1 in 7); $S = 62{\cdot}03$ ft.

$D = 12$; $\alpha = 5^\circ\ 30'$ (1 in 10); $S = 56{\cdot}74$ ft.

$D = 13$; $\alpha = 5^\circ\ 30'$ (1 in 10); $S = 67{\cdot}17$ ft.

$D = 15$; $\alpha = 5^\circ\ 30'$ (1 in 10); $S = 88{\cdot}03$ ft.

This supposes the portion of the crossover covered by S to be straight from nose to nose. It may be, however, less than the calculated distance, making the crossover serpentine, but must on no account be more.

V.—A DIAGONAL OR PICK-UP LINE.

(1.) In figure 12, let S = distance from nose to nose of successive crossings measured along the line; V = distance measured along the diagonal; D = interval between tracks; α = angle of crossings used. Also let α = angle which the diagonal makes with the main lines.

$$S = D \cot \alpha \quad \text{.....................(32)}$$

$$V = D \operatorname{cosec} \alpha \quad \text{..................(33)}$$

Example 5.—Metre Gauge. $D = 12$; $\alpha = 7^\circ\ 45'$

$$S = 12 \cot 7^\circ\ 45' = 88{\cdot}17 \text{ feet}$$

$$V = 12 \operatorname{cosec} 7^\circ\ 45' = 88{\cdot}99 \text{ feet}$$

(2.) In figure 13, let the diagonal make an angle θ with the main lines; α = angle of crossings used.

$$V = D \operatorname{cosec} \theta \quad \text{..................(34)}$$

To find the positions of the crossings:

$$T = R \tan \frac{\theta - \alpha}{2} \quad \text{..................(35)}$$

$$Y = \frac{T \sin \alpha}{\sin \theta} \quad \text{........................(36)}$$

$$Z = \frac{T \sin (\theta - \alpha)}{\sin \theta} \quad \text{.....................(37)}$$

Example 6.—Metre Gauge. $D = 12$; $\alpha = 7^\circ\ 45'$; θ = "limiting angle" of the diagonal—*i. e.* the greatest angle at which the diagonal should be run across the yard.

When $\theta =$ "limiting angle" (see fig. 13), the butt of the stock-rail of the next points fits directly into the crossing. No piece is put in, and no room is lost between them. If the diagonal be indefinitely extended, each crossing in succession (the intervals between tracks being D) will retain a similar position, and there will be no fear of getting jammed.

The examination of this case will be most useful where economy of space has to be studied in laying out a yard, and will prevent impossible arrangements from being laid down in the plan.

We may take V—crossing, lead, switch, and stock-rail beyond toe of switch included—to be $4'\ 0'' + 44'\ 3'' + 15'\ 1'' = 63{\cdot}33$ feet.

Then $\sin \theta = \frac{12}{63{\cdot}33}$, and $\theta = 10^\circ\ 55'$.

The diagonal should not have, therefore, a greater angle than $10^\circ\ 55'$; and this is the "limiting angle" for a diagonal from which a series of 1 in 7 crossings branch off into sidings, the least interval between tracks being 12 feet.

To determine the positions of the crossings, we shall find

$$\begin{array}{lcll} T & = & 2{\cdot}764 \text{ metres, or} & 9'\ 0'' \\ Y & = & 1{\cdot}968 \quad ,, \quad ,, & 6'\ 5''\tfrac{1}{2} \\ Z & = & 0{\cdot}806 \quad ,, \quad ,, & 2'\ 7''\tfrac{3}{4} \end{array}$$

EXAMPLE 7.—In figure 14, let a 1 in 10 crossing run into the direction of a 1 in 7 diagonal, so that $\beta = 5^\circ\ 30'$, and $\alpha = 7^\circ\ 45'$. This case will often occur in entering a station yard.

If T be the tangent of the curve which carries the direction of the 1 in 10 crossing into that of the 1 in 7 crossing:

$$\begin{aligned} T &= R \tan \frac{\alpha - \beta}{2} \\ &= 200 \tan 1^\circ\ 7'\ 30'' \\ &= 3{\cdot}93 \text{ metres} \end{aligned}$$

If U be the distance from the nose of the 1 in 10 crossing to the point from which the 1 in 7 diagonal would strike off on the same line:

$$U = \frac{T \sin(\alpha - \beta)}{\sin \beta}$$

$$= 1{\cdot}14 \text{ metres, or } 3'\ 9''$$

Hence, if D be 12 feet, the total distance S from nose of 1 in 10 crossing to nose of 1 in 7 crossing, measured along the line, is 91′ 11″. Thus:

$$S = 88'\ 2'' + 3'\ 9'' = 91'\ 11''.$$

VI.–METRE GAUGE CROSSING BROAD GAUGE.

In figure 15, let the metre-gauge line lie symmetrically between the broad-gauge rails, and the radius of the curve be 100 metres, or 328 feet. This is the least admissible radius, and the greatest radius that will enable us to cross the broad-gauge line conveniently.

Then the inner rail will cross the broad-gauge rail at an inclination of 1 in 12 at D. Thus:

$$I = \sqrt{\frac{R}{2NB}} = \sqrt{\frac{328}{2{\cdot}22}} = 12$$

From this point D the metre-gauge line may be carried straight on, in which case the outer rail will also cross the broad-gauge rail at the same inclination, 1 in 12, at C_2; or the same curve may be continued, in which case it will cross at an inclination of 1 in 6 at C_1. Thus:

$$I = \sqrt{\frac{328}{2 \times 4{\cdot}39}} = 6$$

If it be convenient to use either a 1 in 7 or a 1 in 10 crossing, it will be placed at a suitable point intermediate between C_1 and C_2.

VII.—TRIANGLES.

The case of Triangles will be best illustrated by two examples.

EXAMPLE 8.—In figure 16, let A and B be 1 in 7 crossings, C a 1 in 5 crossing, and let the radius of the curves be 100 metres, or 328 feet.

Then we have:

$$
\begin{aligned}
T &= R \cot \frac{103^\circ\ 15'}{2} \\
&= 259{\cdot}74 \text{ feet} \\
P &= \frac{T \sin 5^\circ\ 30'}{\sin 97^\circ\ 45'} \\
&= 25{\cdot}12 \text{ feet} \\
M &= (P+T) \cos 7^\circ\ 45' \\
&= 282{\cdot}26 \text{ feet} \\
N &= M \tan 7^\circ\ 45' \\
&= 38{\cdot}41 \text{ feet} \\
H &= N+(H-N) \\
&= N + \frac{T \sin 76^\circ\ 45'}{\sin 97^\circ\ 45'} \\
&= 293{\cdot}57 \text{ feet.}
\end{aligned}
$$

Having the measurements M and H, we can now fix the positions of the crossings on the ground.

The half-angle of intersection of tangents is $3097'{\cdot}5$. If X be the length of the curve between A and C, or B and C:

$$
\begin{aligned}
X &= 0.000582R\,(5400-3097{\cdot}5) \\
&= 439{\cdot}54
\end{aligned}
$$

We can now lay down lines of the proper length between A and C, B and C, and these can be adjusted afterwards to the proper curve.

EXAMPLE 9.—Let the triangle be equilateral, and each crossing a 1 in 5.

Suppose, *e.g.*, that at the end of a siding a 1 in 5 crossing *has been laid in* (see fig. 17) from which two sides of the triangle diverge, the third side being opposite. This case gives the smallest triangle which can be put in on a metre-gauge railway, the least admissible radius being 100 metres.

Let Q be the distance of either crossing from the other two. Then:

$$\begin{aligned} T &= R \cot 65^\circ\, 30' \\ &= 149{\cdot}48 \\ Q &= 2T \cos 24^\circ\, 30' \\ &= 272{\cdot}04 \end{aligned}$$

And if X be the length of the curve between any two of the crossings:

$$\begin{aligned} X &= 0{\cdot}000582\, R\, (5400 - 3930) \\ &= 280{\cdot}62 \end{aligned}$$

VIII.—GENERAL REMARKS.

The object of the guard-rail being to prevent trains from mounting the crossing, it should be placed well towards the front of the nose. It is often placed so far back as to show that the plate-layer was not thinking of its use.

It is wrong to use too many long sleepers. At a short distance from the crossing it is better to use short sleepers, so that the dividing roads may be independently adjustable. The sleeper of one road should cross and touch the nearly opposite sleeper of the other road, so that the two may be easily packed at the same time.

As before observed, leads are to be measured from heel of switch to an imaginary point, coinciding with the point of intersection of the lines of the crossing, and several inches in front of the blunt nose—further in front, of course, as the crossing is more acute.

When a plate-layer once sees how simple are the calculations for setting out lines accurately, the guess-work process will be abandoned.

RECAPITULATION OF USEFUL FORMULÆ.

I.—LAYING OUT CURVES.

(*See fig.* 2.)

$O = \dfrac{C^2}{R} = 8v$ (approximately) ....(1)

θ (in minutes) $= \dfrac{1719C}{R}$ ....(2)

$T = R \cot \phi$ ....(3)

$C = 2\sqrt{(2R - v)v} = \sqrt{8Rv}$ (approximately) (4)

$v = R - \sqrt{R^2 - \left(\frac{C}{2}\right)^2} = \dfrac{C^2}{8R}$ (approximately) (5)

$X = 0{\cdot}000582R\,(5400 - \phi)$ ....(6)

(where ϕ is expressed in minutes)

$Y = R\,(\operatorname{cosec} \phi - 1)$ ....(7)

$V = R\,(\text{coversine } \phi)$ ....(8)

$R = \dfrac{2864{\cdot}8}{n}$ ....(9)

(where n = no. of degrees for 100 feet chords)

II.—SERPENTINE CURVES.

(*See fig.* 3.)

$\cos \beta = \dfrac{r + (R - D_1) \cos \delta}{R + r}$ ....(10)

$\cos \alpha = \dfrac{R + (r - D_2) \cos \delta}{R + r}$ ....(11)

$\beta - \alpha = \delta$ ....(12)

If the lines are parallel, $D = D_1$ or D_2; and if $R = r$:

$\cos \alpha = \cos \beta = \dfrac{2R - D}{2R}$ ....(13)

III.—DIVERSIONS.

(*See fig.* 4.)

$$c = \sqrt{\left(R - \frac{O}{4}\right)O} = \sqrt{OR} \text{ (approximately)} \quad (14)$$

IV.—CANT ON CURVES.

$$E = G\frac{V^2}{1{\cdot}25R} \cdots\cdots\cdots\cdots (15)$$

(where E is expressed in inches, V in miles per hour, G and R in feet)

$$E = G\frac{V^2}{32R} \cdots\cdots\cdots\cdots (16)$$

(where E, G, V are all expressed in the same unit, the unit of time being one second)

V.—POINTS AND CROSSINGS.

(1.) (*See fig.* 5.)

$$I = \cot a \cdots\cdots\cdots\cdots (17)$$

$$R = G \text{ versin } a \cdots\cdots\cdots\cdots (18)$$

$$L' = R \sin a \cdots\cdots\cdots\cdots (19)$$

$$L' = G \cot \frac{a}{2} = 2GI \text{ (approximately)} \cdots\cdots (20)$$

$$L' = \sqrt{(2R - G)G} = \sqrt{2RG} \text{ (approx.)} \cdots (21)$$

(*See fig.* 6.)

$$\left\{\begin{array}{ll} L' = \sqrt{\dfrac{2RrG}{R+r}} & \text{for diverging curves} \cdots\cdots (22) \\[2ex] L' = \sqrt{\dfrac{2RrG}{R-r}} & \text{for converging curves} \cdots\cdots (23) \end{array}\right.$$

$$l' = \sqrt{2Rd} \cdots\cdots\cdots\cdots (24)$$

$$L = L' - l' \cdots\cdots\cdots\cdots (25)$$

N.B.—If rough rules for leads are required, engineers can easily make them for the use of inspectors. Thus, for metre gauge, multiply the number of the crossing by 5.

For crossings 1 in 5, 7, 10, 6¾, 9½, and 12, the leads so obtained are respectively 25, 35, 50, 34, 47½, and 60, which are near enough for use.

(2.) (*See fig.* 7.)

$$\sin\delta = \frac{d}{l} \tag{26}$$

$$L = (G - d)\cot\frac{a+\delta}{2} \tag{27}$$

$$I = \sqrt{\frac{R}{2G}} \tag{28}$$

$$I = \sqrt{\frac{Rr}{2(R-r)G}} \text{ for converging curves} \tag{29}$$

$$I = \sqrt{\frac{Rr}{2(R+r)G}} \text{ for diverging curves} \tag{30}$$

VI.—CROSSOVERS.

(*See fig.* 11.)

$$S = (D - 2G)\cot a \tag{31}$$

VII.—DIAGONALS, OR PICK-UP LINES.

(*See fig.* 12 *and fig.* 13.)

(1.) In figure 12,

$$S = D\cot a \tag{32}$$

$$V = D\,\text{cosec}\,a \tag{33}$$

(2.) In figure 13,

$$V = D\,\text{cosec}\,\theta \tag{34}$$

$$T = R\tan\left(\frac{\theta-a}{2}\right) \tag{35}$$

$$Y = \frac{T\sin a}{\sin\theta} \tag{36}$$

$$Z = \frac{T\sin(\theta-a)}{\sin\theta} \tag{37}$$

PLAIN RULES FOR BEGINNERS.

(1.) *To lay out a curve in* 100 *ft. chords by offsets.*—

Divide 10,000 by the radius in feet. This gives the full offset. From the first point produce the tangent to a distance of 100 feet. Set off half the offset. This fixes the second point on the curve. Join the first and second points, and produce this line to a distance of 100 feet beyond the second point. Set off the full offset. This fixes the third point on the curve. Joining the second and third points, producing this line to a distance of 100 feet beyond the third point, and thence setting off the full offset, you fix the fourth point. Continue this process until you reach the end of the curve.

(2.) *To lay out diversions.*—

Your curve must have a certain radius, R; and your line must have a certain divergence, O. Multiply O by R and take the square root of the result. This gives c, one-fourth of the whole length of the diversion. From the position of greatest divergence, which will be the third or centre point on the line, measure along the straight line, in opposite directions, c to fix the second and fourth points, and $2c$ to to fix the first and fifth (or last) points on the line. At the first point the line begins to diverge. At the second point the divergence $= \frac{O}{2}$, and the curve changes. At the third or centre the greatest divergence, O, is attained. At the fourth point the divergence again $= \frac{O}{2}$, and the curve changes. At the fifth point the diversion runs into the original line.

It is a good thing to allow room for a piece of straight between the changes of curve.

Probably at the centre of the diversion a piece of straight will be necessary, depending on the purpose for which the diversion is required, and allowance can easily be made for that.

You have been advised already how to test the evenness of your curves.

(3.) *To find the cant required on curves.*—

Ask your engineer to decide how long a chord you should always stretch with your tape along any curve. Measure with your foot rule the distance from tape to rail at centre. This will give the cant which you ought to put on that particular curve.

(4.) *To find the number and inclination of a crossing.*—

Lay strings along the edges of the crossings. Measure the distance from the nose of the crossing at which the strings are 1 foot apart. This distance gives the divergence or number of the crossing, and $= I$. If this distance is $7\frac{1}{4}$ feet, for example, the number of the crossing is $7\frac{1}{4}$, or roughly 7; and the inclination is 1 in $7\frac{1}{4}$, or is roughly called 1 in 7.

(5.) *To set off the direction of a crossing.*—

Divide 100 by the number, I, of the crossing. This gives the required offset. Measure back 100 feet from the nose of the crossing along the straight rail. Set off the offset perpendicularly to the rail. This point and the nose of the crossing are in the required direction. In this way you can carry on the direction of a crossing accurately as far as you require.

(6.) *To find the lead of a crossing.*—

Multiply twice the gauge by the divergence or number, I, of the crossing (in other words, follow the Plate-layer's Rule), and subtract the length of the switch. Thus:

$$L = 2GI - l$$

This rule depends on the incorrect assumption that the curve proper to the crossing coincides exactly with the line of the switch and so finally touches the gauge-line of the stock-rail coincidently with the toe of the switch.

For metre-gauge crossings, 1 in 7·35 and 1 in 10·43, with 12 ft. switches, the leads thus obtained are 36¼ ft. and 56½ ft., which are quite near enough for ordinary use.

(7.) *To find the distance from crossing to crossing (measured along the straight) in a crossover.*

From the distance between centres of tracks subtract twice the gauge, and multiply by I, the number or divergence of the crossings.

The rule may be written as a formula thus:

$$S = (D - 2G)I$$

Remember that S must not be more than this, but it may be made rather less, if there is not much room to spare.

I have put a few rules in this simple form for the sake of those who are anxious to calculate their measurements accurately, but who do not like the look of a mathematical formula. But the man who has reached the point of wishing to work out things for himself need not be frightened by difficulties which are only imaginary. Those apparently formidable signs have very simple meanings, and an engineer could with very little trouble and in a very little time explain those to him, so that he could use every formula in this little book.

THE END.

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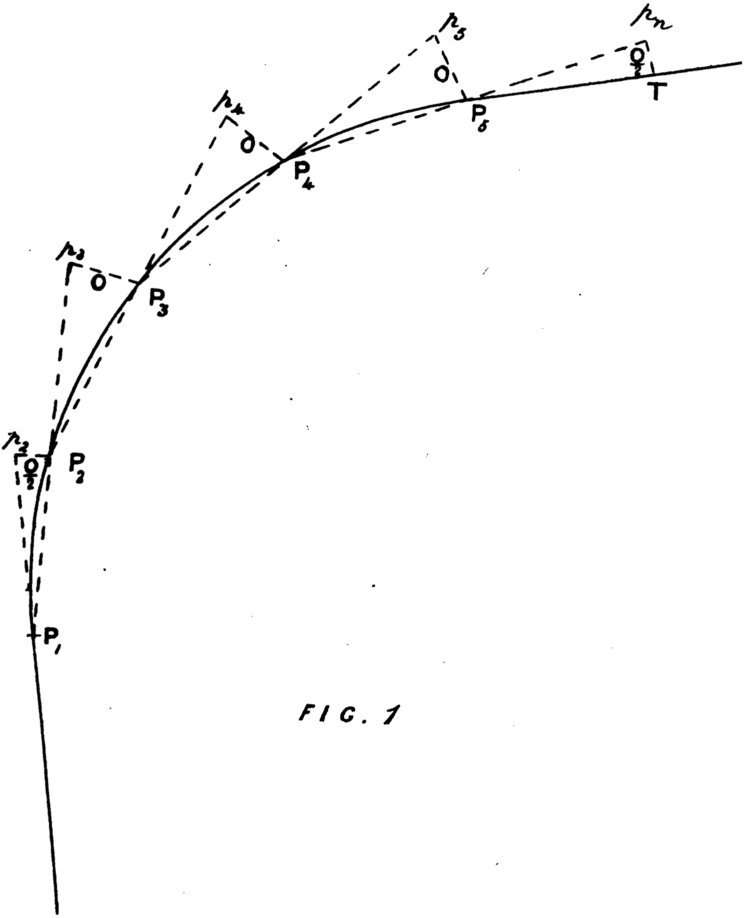
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$\frac{\theta}{2}$
T
P_5
P_4
P_3
P_2
P_1

FIG. 1

The general case may be treated in two different ways. For simplicity, the main line will be assumed to be straight, but it will be seen afterwards that the application to cases where the lines are curved is very easy.

(1.) The first and usual method of calculating the lead is as follows:—

For a given gauge and crossing a certain curve can be found which would rest tangentially on the gauge-line and the crossing. This curve, however, would only be continued for a certain distance from the nose of the crossing, viz. to the point at which its offset from the gauge-line would be the same as the clearance of the switch. This distance is called the Lead. From that point the line is continued by the switch, the toe of which touches the gauge-line of the main rail.

Referring to figure 5, we have—

$$I = \cot \alpha \quad \text{..........} (17)$$

$$R = \frac{G}{\operatorname{versin} \alpha} \quad \text{..........} (18)$$

$$L' = R \sin \alpha \quad \text{..........} (19)$$

$$\left.\begin{aligned} L' &= G \cot \frac{\alpha}{2} \\ &= 2GI \text{ (approximately)} \end{aligned}\right\} \quad \text{..........} (20)$$

The latter approximate formula is the well-known Platelayer's Rule for the Lead—viz.: Multiply twice the gauge by the number of the crossing. This, however, it must be carefully observed, does not really give the lead. Like the two preceding formulæ, it merely gives the distance from nose of crossing to springing of curve, supposing that the curve were continued until it touched the gauge-line, instead of being intercepted by the switch. From that distance a deduction will have to be made to obtain the lead.

Continuing the formulæ:

$$\left.\begin{aligned} L' &= \sqrt{(2R-G)G} \\ &= \sqrt{2RG} \text{ approximately} \end{aligned}\right\} \text{......(21)}$$

In the same way, when we have curve leaving curve, instead of curve leaving straight, the formulæ—

$$L' = \sqrt{\frac{2RrG}{R+r}} \text{ ....(22)}$$

for curves diverging, and

$$L' = \sqrt{\frac{2RrG}{R-r}} \text{ ....(23)}$$

for curves converging, may be used. These are easily obtained.

Thus, if s and $G \pm s$ be the distances from the nose of the crossing to the tangential gauge-lines at springing produced, as in fig. 6—

$$\left.\begin{aligned} L' &= \sqrt{2Rs} \\ L' &= \sqrt{2r(G \pm s)} \end{aligned}\right\}$$

and eliminating s,

$$L' = \sqrt{\frac{2RrG}{R \pm r}}$$

Once having found the crossing, however, which will suit curve leaving straight or curve leaving curve, the lead will be the same for that crossing in any case.

Thus, whether on the metre gauge a 1 in 6¾ crossing be put in for a 300-ft. curve leaving straight, or for two 600-ft. curves, the lead will be 31 ft.

Continuing the formulæ:

$$l' = \sqrt{2Rd} \text{ ....(24)}$$

and finally,

$$\begin{array}{rcll} \mathrm{L} & = & \mathrm{L}' - l' & \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(25) \\ & = & \left.\begin{array}{l} \mathrm{R} \sin a \\ \mathrm{G} \cot \frac{a}{2} \\ 2\mathrm{GI} \\ \sqrt{(2\mathrm{R}-\mathrm{G})\mathrm{G}} \\ \sqrt{2\mathrm{RG}} \end{array}\right\} & - \sqrt{2\mathrm{R}d} \\ \textit{or } \mathrm{L} & = & \sqrt{\dfrac{2\mathrm{R}r\mathrm{G}}{\mathrm{R} \pm r}} & - \sqrt{\dfrac{2\mathrm{R}rd}{\mathrm{R} \pm r}} \end{array}$$

By the first method, then, the lead is calculated without reference to the length of the switch. It is assumed that a switch of suitable length will be used having the given clearance d.

Example 1.—Let $\mathrm{G} = 1$ metre;
$a = 7^\circ\ 45'$;
$d = 0{\cdot}09$ metre:

Then,

$$\begin{array}{rcccl} & & & & \textbf{Metres.} \\ \mathrm{R} & = & \dfrac{1}{\text{versine } 7^\circ\ 45'} & = & 109{\cdot}48 \\ \mathrm{L}' & = & \mathrm{R} \sin 7^\circ\ 35' & = & 14{\cdot}76 \\ l' & = & \sqrt{2\mathrm{R} \times 0{\cdot}09} & = & 4{\cdot}44 \\ \mathrm{L} & = & \mathrm{L}' - l' & = & 10{\cdot}32, \text{ or } 33{\cdot}85 \text{ ft.} \end{array}$$

(**2.**) It generally happens that a certain crossing and switch are given to be used together, and in the second method of calculation the length and divergence of the switch are taken into account, the directions of the switch and crossing being assumed to be tangential to the curve where it meets the heel of the switch and the nose of the crossing.

Referring to figure 7, we have—

$$\sin \delta = \frac{d}{l} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (26)$$

Again,

$$\begin{aligned} \angle \mathrm{CED} &= \angle \mathrm{KCE} \\ &= \angle \mathrm{KCF} + \angle \mathrm{FCE} \\ &= \angle \mathrm{KCF} + \angle \mathrm{FEC} \\ &= \delta + \alpha - \angle \mathrm{CED} \end{aligned}$$

But

$$\therefore \angle \mathrm{CED} = \frac{\alpha+\delta}{2}$$

Again,

$$\begin{aligned} \mathrm{L} &= \mathrm{DE} \\ &= \mathrm{CD} \cot \mathrm{CED} \\ \therefore \mathrm{L} &= (\mathrm{G}-d) \cot \frac{\alpha+\delta}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (27) \end{aligned}$$

EXAMPLE 2.—Let

$$\begin{aligned} \mathrm{G} &= 1 \text{ metre} \\ l &= 3{\cdot}63 \text{ metres} \\ d &= 0{\cdot}09 \text{ metre} \\ \alpha &= 7^{\circ}\ 45' \end{aligned}$$

these dimensions being taken from the Type Drawings for Indian State Railways.

Then,

$$\begin{aligned} \sin \delta &= \frac{0{\cdot}09}{3{\cdot}63} \\ \therefore \delta &= 1^{\circ}\ 25' \\ \mathrm{L} &= (\mathrm{G}-d) \cot \frac{\alpha+\delta}{2} \\ &= 0{\cdot}91 \cot 4^{\circ}\ 35' \\ &= 11{\cdot}35 \text{ metres, or } 37{\cdot}23 \text{ feet.} \end{aligned}$$

In the Type Drawings, however, the radius of the curve is given as 100 metres, and the lead as 44·2 feet; and the dimensions are near enough for all practical purposes, although, as we have seen, they differ a good deal from the results obtained in EXAMPLES 1 and 2.

The lead given in the Type Drawings is apparently calculated from the formula $L' = R \sin \alpha$ (R being taken as 100 metres); and the deduction of l', which is required to obtain L, the correct lead, is not made.

Thus, referring to figure 8,

$$\begin{aligned} R \sin \alpha &= 100 \sin 7^{\circ}\ 45' \\ &= 13{\cdot}48 \text{ metres, or } 44'\ 3'' \end{aligned}$$

This is treating the case as if the curve, instead of running into the heel of the switch, met the gauge-line of the main rail tangentially at the point.

When the accurate lead is put in, we have one even curve having the longest radius possible with the given switch and crossing.

When we put in a longer lead, we have a compound curve, flatter near the switch, and sharper at the crossing, than the proper curve. Looking at a 1 in 7 crossing laid with a 44 ft. or 45 ft. lead, the flatness of the curve towards the heel of the switch and its sharpness towards the nose of the crossing are at once noticed.

It is obvious, therefore, that no advantage is gained, and the radius of the curve is not improved by putting in a longer lead than the correct one. Practically, however, the angle of a crossing is defined by such short lines that small differences in the length of the lead may be allowed. For instance, in practice it is not convenient to cut rails if the lead can be nearly obtained without doing so.

II.—METRE-GAUGE CROSSINGS ON INDIAN STATE RAILWAYS.

The crossings at present in use are known as the 1 in 7, the 1 in 10, and the 1 in 5.

(1.) *The* 1 *in* 7 *Crossing:—*

The angle of a 1 in 7 crossing is 7° 45′, which gives an inclination of 1 in 7·35.

The radius of the curve is given as 100 metres, or 328 ft. in the Type Drawings.

The lead, or distance from nose of crossing to heel of switch, is given as 13·49 metres, or 44′ 3″.

To set off the direction of a 1 in 7 crossing by measurement.—The perpendicular offset at a distance of 100 feet from the nose of the crossing is 13′ 7″5/16. Thus:

$$\begin{aligned} O &= 100 \tan 7^\circ 45', \text{ or } \frac{100}{I} \left(i.e. \frac{100}{7\cdot35}\right) \\ &= 13\cdot61 \text{ feet.} \end{aligned}$$

This rule will enable the plate-layer to produce the direction accurately to any distance across a yard without having to use a theodolite.

To test a 100 metre curve.—The versine on a chord of 50 feet is 11½ inches. Thus:

$$\begin{aligned} v &= \frac{C^2}{8R} \text{ approximately (formula 5)} \\ &= \frac{2500}{2624} = 0\cdot95 \text{ feet} = 11\tfrac{1}{2} \text{ inches} \end{aligned}$$

(2.) *The* 1 *in* 10 *Crossing:—*

The angle of a 1 in 10 crossing is 5° 30′, which gives an inclination of 1 in 10·43.

The radius of the curve is given as 200 metres, or 656 ft.

The lead is given as 19·20 metres, or 63′ 0″. Thus:

$$\begin{aligned} L' &= R \sin \alpha \\ &= 200 \sin 5^\circ\, 30' \\ &= 19{\cdot}2 \text{ metres} \end{aligned}$$

To set off the direction of a 1 in 10 crossing by measurement.—The perpendicular offset at a distance of 100 feet is 9′ 7″½.

To test a 200 metre curve.—The versine on a chord of 50 feet is 5¾ inches.

(3.) *The* 1 *in* 5 *Crossing:*—

The angle of a 1 in 5 crossing is 11° 0′, wihich gives an inclination of 1 in 5·24.

The radius of each of the diverging curves is given as 100 metres, or 328 feet.

The lead is given as 9·54 metres, or 31′ 3″. Referring to figure 9, this is apparently obtained as follows, the deduction necessary to determine the correct lead not being made:—

$$\begin{aligned} R \sin \frac{\alpha}{2} &= 100 \sin 5^\circ\, 30' \\ &= 9{\cdot}58 \text{ metres, or } 31'\ 33'' \end{aligned}$$

To set off the directions.—Each makes with the bisecting line an angle of 5° 30′, the perpendicular offset of which at a distance of 100 feet is 9′ 7″½.

To test the 100 metre curves.—As before, the versine on a chord of 50 feet is 11½ inches.

With Circular No. 4 of 1882 were issued diagrams of Standard Crossings, which have not yet been brought into use. The leads given in these diagrams are as nearly accurate as can be desired in any case.

The crossings are the 1 in 6¾, the 1 in 9½, and the 1 in 12. The following cases may be noted:—

a.—Main line straight; Radius of branch 300 feet; Crossing 1 in 6¾; Angle 8° 30′; Lead 31 feet. This may be easily obtained:

$$\begin{aligned} \mathrm{L} &= \mathrm{L}' - l' = \mathrm{R} \sin \alpha - \sqrt{2\mathrm{R}d} \\ &= 300 \sin 8^\circ 30' - \sqrt{600\left(\tfrac{3\frac{5}{8}}{12}\right)} \\ &= 44 - 13 \\ &= 31 \text{ feet} \end{aligned}$$

b.—Curves diverging; Radius of each 600 feet; Crossing 1 in 6¾; Angle 8° 30′; Lead 31 feet.

c.—Main line straight; Radius of branch 600 feet; Crossing 1 in 9½; Angle 6° 0′; Lead 44 feet.

d.—Main line straight; Radius of branch 950 feet; Crossing 1 in 12; Angle 4° 45′; Lead 55 feet.

e.—Curves diverging; Radius of each 1200 feet; Crossing 1 in 9½; Angle 6° 0′; Lead 44 feet.

Of these arrangements, *a* is only to be used for temporary sidings to which engines are not admitted; *b* and *c* are to be used for ordinary work in stations. *d* and *e* for junctions and similar positions where an easy curve is of more importance than economy of space.

The clearance at heel of switch in these diagrams is 3⅝ inches or 0·30208 feet.

On Indian State Railways the gauge is measured from inside to inside of rail; and the apex of the crossing, being formed by the intersection of the lines of the inside edges of the rails, is an imaginary point a little *in front of* the blunt nose of the crossing.

In Donaldson's books the gauge is measured from centre to centre of rail; and the apex of the crossing, being determined by the intersection of the centre lines of the rails, is an imaginary point a little *behind* the blunt nose of the crossing.

In both cases it is to those imaginary points that all calculations and measurements refer.

If reference is made to Donaldson's "Tables for Platelayers," it must be to Table V. for the metre gauge. It is nominally for 3′ 6″ gauge; but, bearing in mind that this is measured from centre to centre of rail, it is clear that the following measurements quoted from that table very nearly apply:—

CROSSING 1 IN	LEAD.	CROSSING 1 IN	LEAD.
5	26	7½	39
5½	28	8	42
6	31	9	47
6½	34	10	52
7	36	11	57

As regards other portions of the Table, it must be remembered that the clearance at heel of switch, the least admissible radius, the intervals between the roads, and other data on which the calculation of the measurements depends are different from those adopted on Indian State Railways.

III.—*WHAT CROSSINGS TO USE.*

(1.) *Curve branching from Straight:—*

$$I = \frac{1}{\sin \alpha} \text{ approximately}$$

$$= \frac{R}{L'}$$

$$= \frac{R}{\sqrt{(2RG)}}$$

$$\therefore \quad I = \sqrt{\frac{R}{2G}} \quad \cdots\cdots\cdots (28)$$

EXAMPLE 3.— Let R = 100 metres
G = 1 metre

Then, $I = \sqrt{\frac{100}{2 \times 1}} = \sqrt{50} = 7$ nearly

Hence in this case a 1 in 7 crossing would be suitable.

(2.) *Two Converging Curves:—*

In a similar way the formula—

$$I = \sqrt{\frac{Rr}{2(R-r)G}} \quad \cdots\cdots\cdots (29)$$

may be obtained.

EXAMPLE 4.—Let R = 600 metres
r = 150 metres
G = 1 metre

Then, $I = \sqrt{\frac{600 \times 150}{2(600-150) \times 1}}$

$= \sqrt{100}$

$= 10$

(3.) *Two Diverging Curves:—*

$$I = \sqrt{\frac{Rr}{2(R+r)G}} \quad \cdots\cdots\cdots (30)$$

From the above formulæ the following common cases may be easily deduced for metre gauge:—

a.—Main line straight; Radius of branch 200 metres; Crossing 1 in 10.

b.—Main line straight; Radius of branch 100 metres; Crossing 1 in 7.

c.—Curves diverging; Radius of each 100 metres; Crossing 1 in 5.

d.—Curves diverging; Radius of each 200 metres; Crossing 1 in 7.

e.—Curves converging; Radii 200 and 100 metres; Crossing 1 in 10.

f.—Three Throws; Branch Roads (fig. 10*a*) diverging; Radius of each 100 metres; Crossings—A 1 in 5, B_1 and B_2 1 in 7.

g.—Three Throws; Branch Roads diverging; Radius of each 200 metres; Crossings—A 1 in 7, B_1 and B_2 1 in 10.

h.—Three Throws; Branch Roads (fig. 10*b*) converging; Radii 200 and 100 metres respectively; Crossings—A 1 in 7, B_1 and B_2 1 in 10.

IV.—CROSSOVERS.

In figure 11, let D = distance from centre to centre of tracks, and S = distance from nose to nose of crossings measured along the line.

$$S = (D - 2G) \cot \alpha \qquad (31)$$

The following examples for metre gauge may be verified. Most of the tracks on Indian State Railways have so far been laid 12 feet apart, but the rule now is to lay the roads 13 feet and 15 feet apart in different cases:—

$D = 12$; $\alpha = 7^\circ\ 45'$ (1 in 7); $S = 39{\cdot}98$ ft.
$D = 13$; $\alpha = 7^\circ\ 45'$ (1 in 7); $S = 47{\cdot}33$ ft.
$D = 15$; $\alpha = 7^\circ\ 45'$ (1 in 7); $S = 62{\cdot}03$ ft.
$D = 12$; $\alpha = 5^\circ\ 30'$ (1 in 10); $S = 56{\cdot}74$ ft.

$D=13$; $\alpha=5^\circ\,30'$ (1 in 10); $S=67{\cdot}17$ ft.

$D=15$; $\alpha=5^\circ\,30'$ (1 in 10); $S=88{\cdot}03$ ft.

This supposes the portion of the crossover covered by S to be straight from nose to nose. It may be, however, less than the calculated distance, making the crossover serpentine, but must on no account be more.

V.—A DIAGONAL OR PICK-UP LINE.

(1.) In figure 12, let S = distance from nose to nose of successive crossings measured along the line; V = distance measured along the diagonal; D = interval between tracks; α = angle of crossings used. Also let α = angle which the diagonal makes with the main lines.

$$S = D \cot \alpha \quad \ldots\ldots\ldots\ldots\ldots\ldots(32)$$

$$V = D \operatorname{cosec} \alpha \quad \ldots\ldots\ldots\ldots\ldots\ldots(33)$$

Example 5.—Metre Gauge. $D=12$; $\alpha=7^\circ\,45'$

$$S = 12 \cot 7^\circ\,45' = 88{\cdot}17 \text{ feet}$$

$$V = 12 \operatorname{cosec} 7^\circ\,45' = 88{\cdot}99 \text{ feet}$$

(2.) In figure 13, let the diagonal make an angle θ with the main lines; α = angle of crossings used.

$$V = D \operatorname{cosec} \theta \quad \ldots\ldots\ldots\ldots\ldots\ldots(34)$$

To find the positions of the crossings:

$$T = R \tan \frac{\theta - \alpha}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(35)$$

$$Y = \frac{T \sin \alpha}{\sin \theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots(36)$$

$$Z = \frac{T \sin (\theta - \alpha)}{\sin \theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots(37)$$

Example 6.—Metre Gauge. $D=12$; $\alpha=7^\circ\,45'$; $\theta=$ "limiting angle" of the diagonal—*i. e.* the greatest angle at which the diagonal should be run across the yard.

When $\theta =$ "limiting angle" (see fig. 13), the butt of the stock-rail of the next points fits directly into the crossing. No piece is put in, and no room is lost between them. If the diagonal be indefinitely extended, each crossing in succession (the intervals between tracks being D) will retain a similar position, and there will be no fear of getting jammed.

The examination of this case will be most useful where economy of space has to be studied in laying out a yard, and will prevent impossible arrangements from being laid down in the plan.

We may take V—crossing, lead, switch, and stock-rail beyond toe of switch included—to be 4′ 0″ + 44′ 3″ + 15′ 1″ = 63·33 feet.

Then $\sin\theta = \frac{12}{63{\cdot}33}$, and $\theta = 10^\circ\ 55'$.

The diagonal should not have, therefore, a greater angle than 10° 55′; and this is the "limiting angle" for a diagonal from which a series of 1 in 7 crossings branch off into sidings, the least interval between tracks being 12 feet.

To determine the positions of the crossings, we shall find

T = 2·764 metres, or 9′ 0″
Y = 1·968 „ „ 6′ 5″½
Z = 0·806 „ „ 2′ 7″¾

EXAMPLE 7.—In figure 14, let a 1 in 10 crossing run into the direction of a 1 in 7 diagonal, so that $\beta = 5^\circ\ 30'$, and $\alpha = 7^\circ\ 45'$. This case will often occur in entering a station yard.

If T be the tangent of the curve which carries the direction of the 1 in 10 crossing into that of the 1 in 7 crossing:

$$\begin{aligned} T &= R \tan \frac{\alpha - \beta}{2} \\ &= 200 \tan 1^\circ\ 7'\ 30'' \\ &= 3{\cdot}93 \text{ metres} \end{aligned}$$

If U be the distance from the nose of the 1 in 10 crossing to the point from which the 1 in 7 diagonal would strike off on the same line:

$$U = \frac{T \sin(\alpha - \beta)}{\sin \beta}$$

$$= 1{\cdot}14 \text{ metres, or } 3'\ 9''$$

Hence, if D be 12 feet, the total distance S from nose of 1 in 10 crossing to nose of 1 in 7 crossing, measured along the line, is 91′ 11″. Thus:

$$S = 88'\ 2'' + 3'\ 9'' = 91'\ 11''.$$

VI.–METRE GAUGE CROSSING BROAD GAUGE.

In figure 15, let the metre-gauge line lie symmetrically between the broad-gauge rails, and the radius of the curve be 100 metres, or 328 feet. This is the least admissible radius, and the greatest radius that will enable us to cross the broad-gauge line conveniently.

Then the inner rail will cross the broad-gauge rail at an inclination of 1 in 12 at D. Thus:

$$I = \sqrt{\frac{R}{2NB}} = \sqrt{\frac{328}{2{\cdot}22}} = 12$$

From this point D the metre-gauge line may be carried straight on, in which case the outer rail will also cross the broad-gauge rail at the same inclination, 1 in 12, at C_2; or the same curve may be continued, in which case it will cross at an inclination of 1 in 6 at C_1. Thus:

$$I = \sqrt{\frac{328}{2 \times 4{\cdot}39}} = 6$$

If it be convenient to use either a 1 in 7 or a 1 in 10 crossing, it will be placed at a suitable point intermediate between C_1 and C_2.

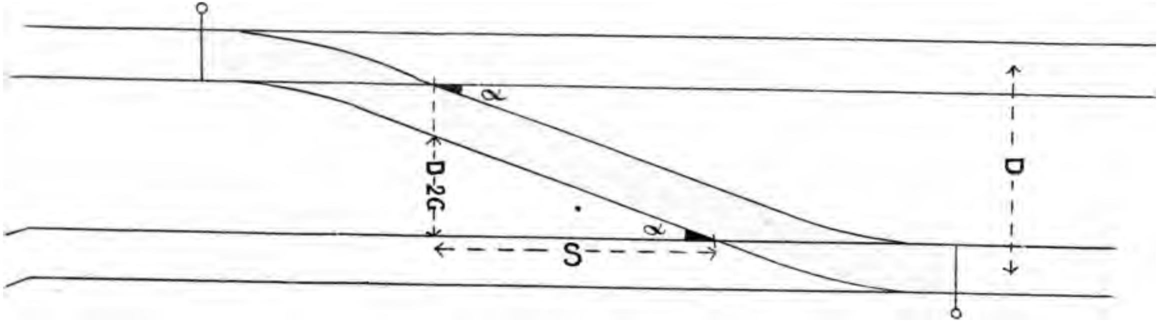

FIG. 11

triangle diverge, the third side being opposite. This case gives the smallest triangle which can be put in on a metre-gauge railway, the least admissible radius being 100 metres.

Let Q be the distance of either crossing from the other two. Then:

$$\begin{aligned} T &= R \cot 65^\circ\ 30' \\ &= 149{\cdot}48 \\ Q &= 2T \cos 24^\circ\ 30' \\ &= 272{\cdot}04 \end{aligned}$$

And if X be the length of the curve between any two of the crossings:

$$\begin{aligned} X &= 0{\cdot}000582\, R\, (5400 - 3930) \\ &= 280{\cdot}62 \end{aligned}$$

VIII.—GENERAL REMARKS.

The object of the guard-rail being to prevent trains from mounting the crossing, it should be placed well towards the front of the nose. It is often placed so far back as to show that the plate-layer was not thinking of its use.

It is wrong to use too many long sleepers. At a short distance from the crossing it is better to use short sleepers, so that the dividing roads may be independently adjustable. The sleeper of one road should cross and touch the nearly opposite sleeper of the other road, so that the two may be easily packed at the same time.

As before observed, leads are to be measured from heel of switch to an imaginary point, coinciding with the point of intersection of the lines of the crossing, and several inches in front of the blunt nose—further in front, of course, as the crossing is more acute.

When a plate-layer once sees how simple are the calculations for setting out lines accurately, the guess-work process will be abandoned.

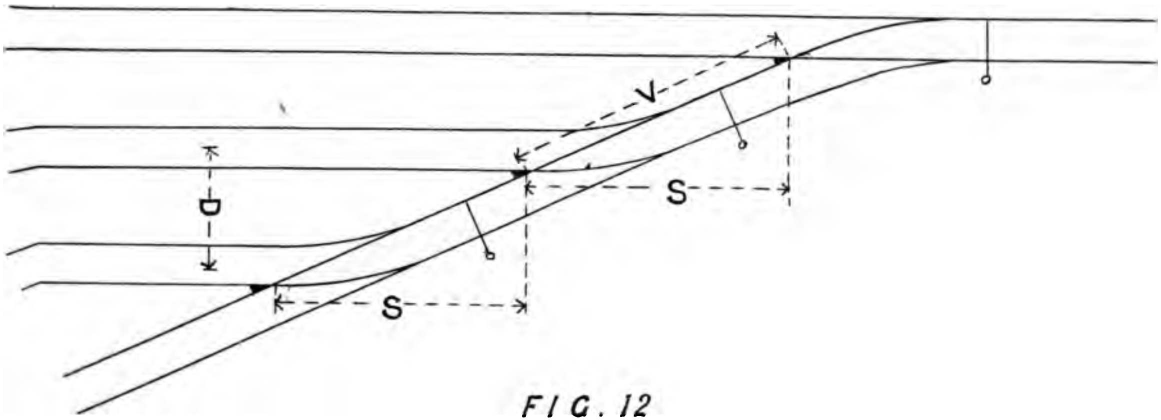

FIG. 12

III.—DIVERSIONS.

(*See fig.* 4.)

$c = \sqrt{(R - \frac{O}{4})O} = \sqrt{OR}$ (approximately) (14)

IV.—CANT ON CURVES.

$E = G\frac{V^2}{1 \cdot 25R}$ ....(15)

(where E is expressed in inches, V in miles per hour, G and R in feet)

$E = G\frac{V^2}{32R}$ ....(16)

(where E, G, V are all expressed in the same unit, the unit of time being one second)

V.—POINTS AND CROSSINGS.

(1.) $I = \cot a$ ....(17)

(*See fig.* 5.) $R = G \operatorname{versin} a$ ....(18)

$L' = R \sin a$ ....(19)

$L' = G \cot \frac{a}{2} = 2GI$ (approximately) ....(20)

$L' = \sqrt{(2R - G)G} = \sqrt{2RG}$ (approx.) ...(21)

(*See fig.*6.) $L' = \sqrt{\frac{2RrG}{R+r}}$ for diverging curves ......(22)

$L' = \sqrt{\frac{2RrG}{R-r}}$ for converging curves ......(23)

$l' = \sqrt{2Rd}$ ....(24)

$L = L' - l'$ ....(25)

N.B.—If rough rules for leads are required, engineers can easily make them for the use of inspectors. Thus, for metre gauge, multiply the number of the crossing by 5.

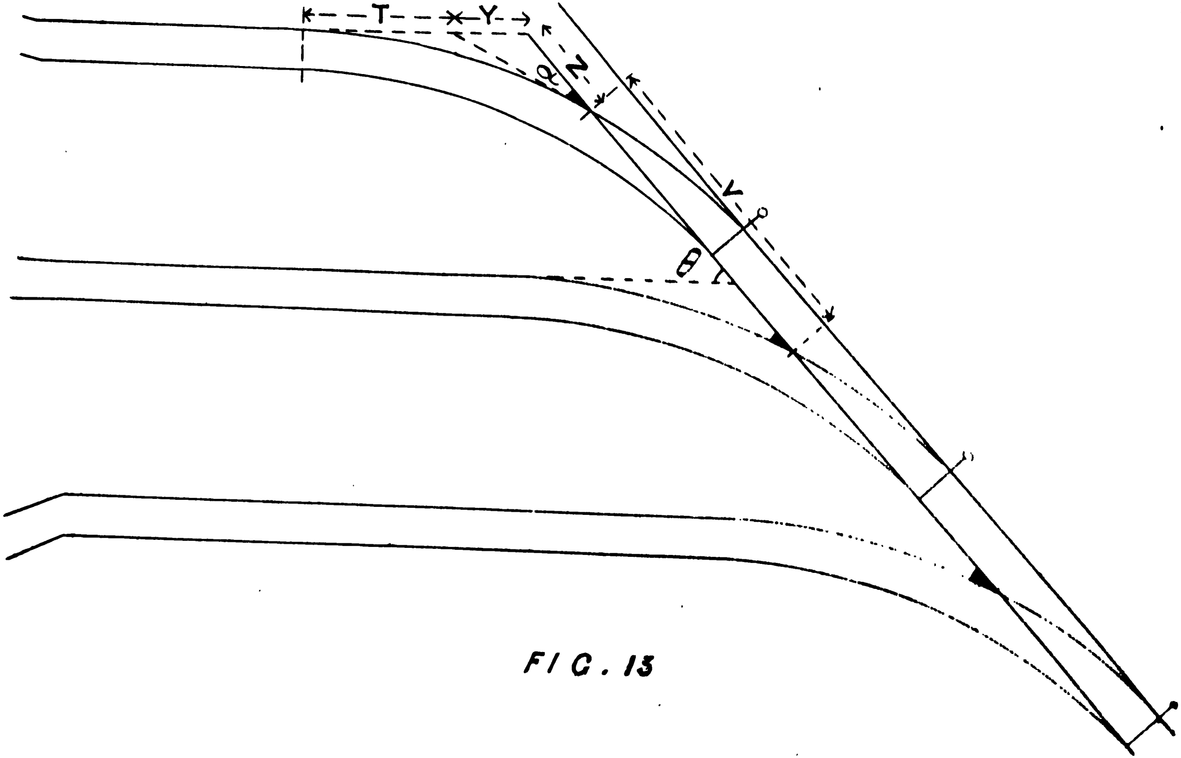

FIG. 13

PLAIN RULES FOR BEGINNERS.

(1.) *To lay out a curve in* 100 *ft. chords by offsets.—*

Divide 10,000 by the radius in feet. This gives the full offset. From the first point produce the tangent to a distance of 100 feet. Set off half the offset. This fixes the second point on the curve. Join the first and second points, and produce this line to a distance of 100 feet beyond the second point. Set off the full offset. This fixes the third point on the curve. Joining the second and third points, producing this line to a distance of 100 feet beyond the third point, and thence setting off the full offset, you fix the fourth point. Continue this process until you reach the end of the curve.

(2.) *To lay out diversions.—*

Your curve must have a certain radius, R; and your line must have a certain divergence, O. Multiply O by R and take the square root of the result. This gives *c*, one-fourth of the whole length of the diversion. From the position of greatest divergence, which will be the third or centre point on the line, measure along the straight line, in opposite directions, *c* to fix the second and fourth points, and 2*c* to to fix the first and fifth (or last) points on the line. At the first point the line begins to diverge. At the second point

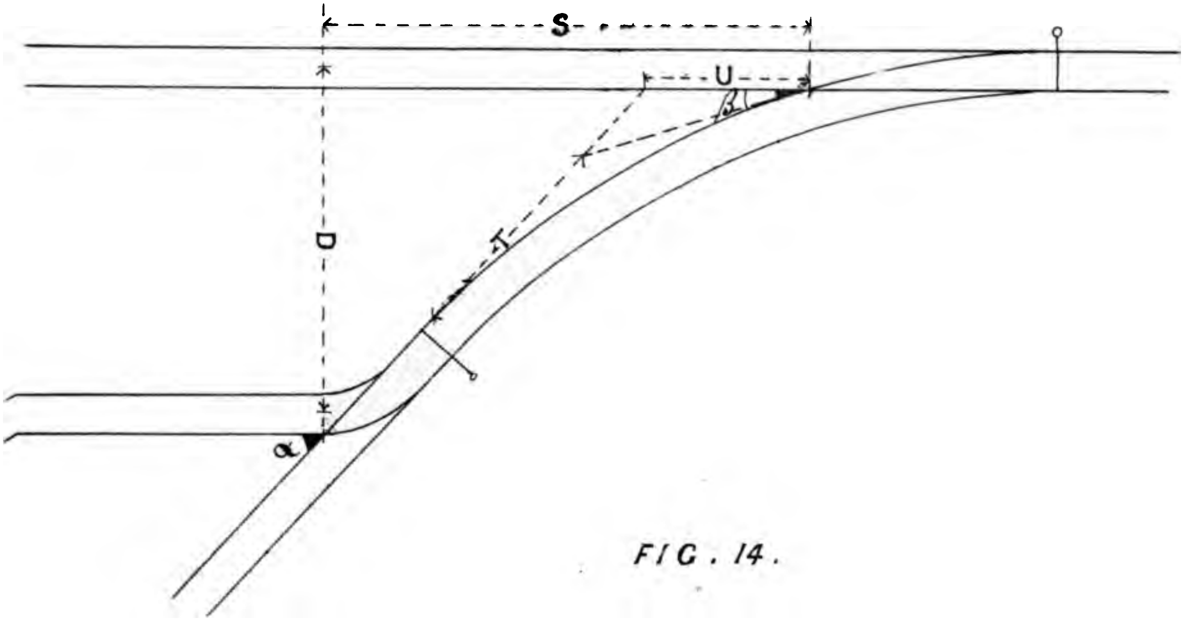

FIG. 14.

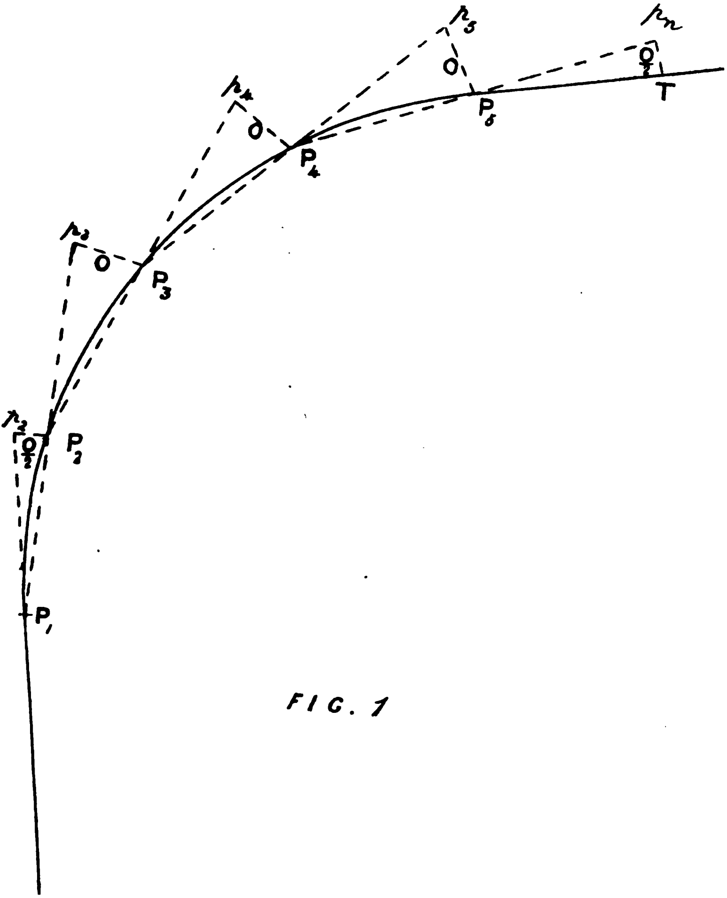

FIG. 1

Remember that S must not be more than this, but it may be made rather less, if there is not much room to spare.

I have put a few rules in this simple form for the sake of those who are anxious to calculate their measurements accurately, but who do not like the look of a mathematical formula. But the man who has reached the point of wishing to work out things for himself need not be frightened by difficulties which are only imaginary. Those apparently formidable signs have very simple meanings, and an engineer could with very little trouble and in a very little time explain those to him, so that he could use every formula in this little book.

THE END.

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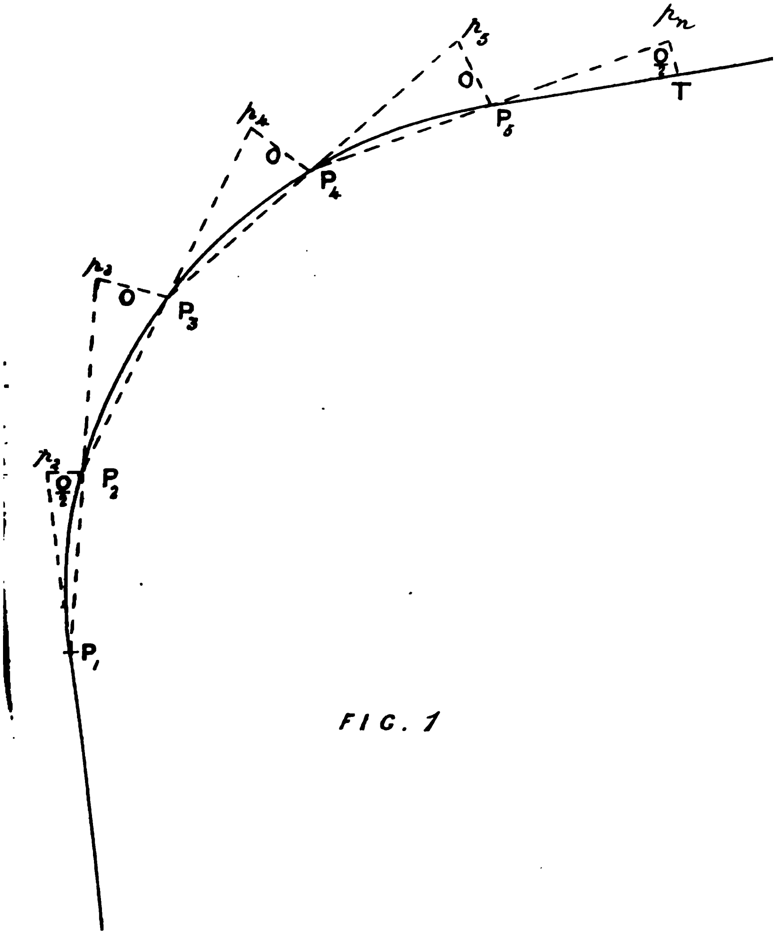

FIG. 1

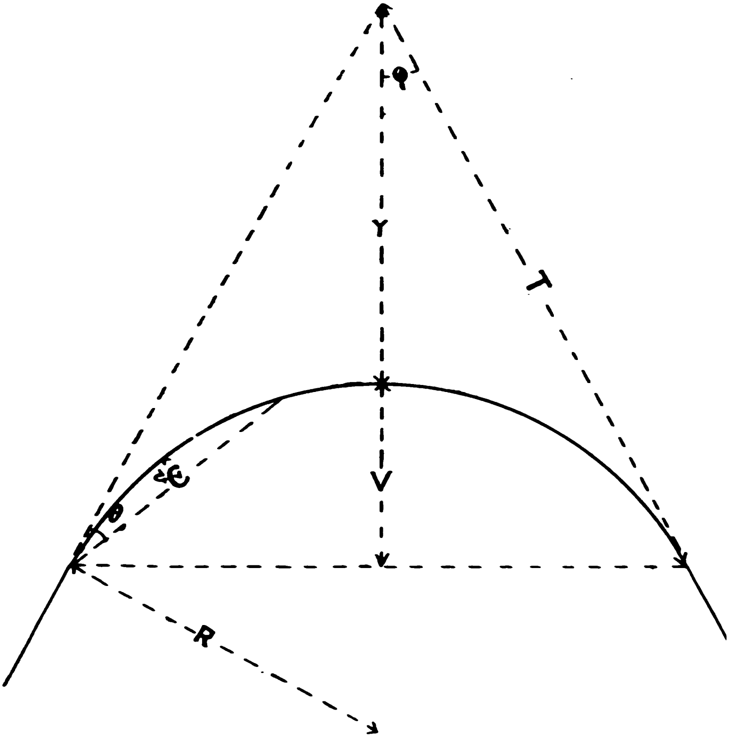

FIG. 2.

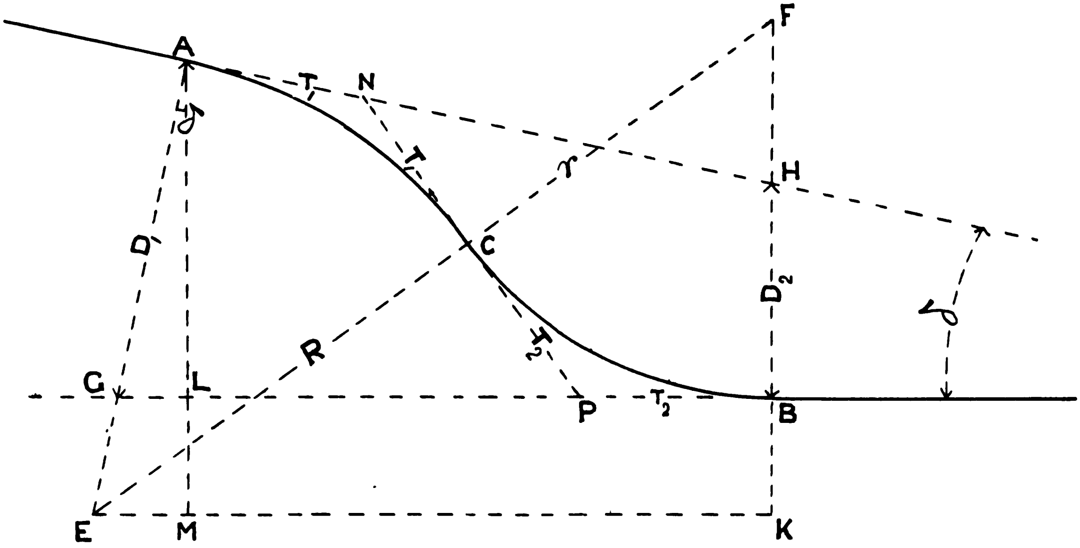

FIG. 3

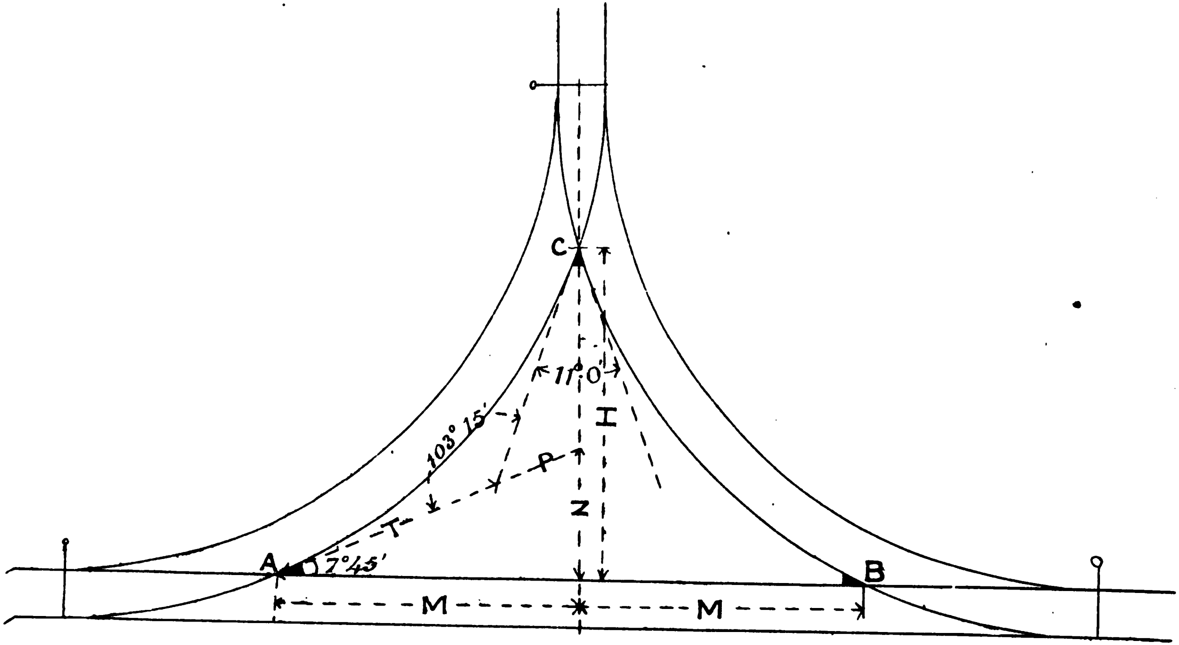

FIG. 16.